

## CLAIMS:

1. A composition of matter useful for sequestering target metal-ions from an environment, said composition comprising a polymer and derivatized nanoparticles comprising inorganic nanoparticles having an attached metal-ion sequestrant, wherein said inorganic nanoparticles have an average particle size of less than 200 nm and the derivatized nanoparticles have a stability constant greater than  $10^{10}$  with iron (III). ✓
2. The composition of claim 1 wherein the environment is a liquid medium and wherein the polymer is permeable to said liquid medium.
3. The composition of claim 1 wherein the environment is an aqueous medium and wherein the polymer is permeable to said aqueous medium.
4. The composition of claim 1 where the polymer has a water permeability of greater than  $1000 [(cm^3 cm)/(cm^2 sec/Pa)] \times 10^{13}$ .
5. The composition of claim 1 where the polymer has a water permeability of greater than  $5000 [(cm^3 cm)/(cm^2 sec/Pa)] \times 10^{13}$ .
6. The composition of claim 1 wherein the polymer comprises one or more of polyvinyl alcohol, cellophane, water-based polyurethanes, polyester, nylon, high nitrile resins, polyethylene-polyvinyl alcohol copolymer, polystyrene, ethyl cellulose, cellulose acetate, cellulose nitrate, aqueous latexes, polyacrylic acid, polystyrene sulfonate, polyamide, polymethacrylate, polyethylene terephthalate, polystyrene, polyethylene and polypropylene or polyacrylonitrile or copolymers thereof.
7. The composition of claim 1 wherein the derivatized nanoparticles are 0.1 to 50.0 % by weight of the polymer.

8. The composition of matter of claim 1 wherein said inorganic nanoparticles have an average particle size of less than 100 nm.

5 9. The composition of matter of claim 1 wherein said inorganic nanoparticles have an average particle size of less than 20 nm.

10 10. The composition of matter of claim 1 wherein said inorganic nanoparticles comprise silica oxides, alumina oxides, boehmites, titanium oxides, zinc oxides, tin oxides, zirconium oxides, yttrium oxides, hafnium oxides, clays, or alumina silicates.

11. The composition of matter of claim 10 wherein said inorganic nanoparticles comprise silicon dioxide, alumina oxide, clays or boehmite.

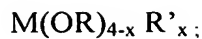
15 12. The composition of matter of claim 1 wherein said metal-ion sequestrant has a high stability constant with copper, zinc, aluminum or heavy metals.

20 13. The composition of matter of claim 1 wherein said metal-ion sequestrant has a stability constant with iron greater than  $10^{20}$ .

14. The composition of matter of claim 1 wherein said metal-ion sequestrant has a stability constant with iron greater than  $10^{30}$ .

25 15. The composition of matter of claim 1 wherein said metal-ion sequestrant comprises an alpha amino carboxylate, a hydroxamate, or a catechol functional group.

30 16. The composition of matter of claim 1 wherein the metal-ion sequestrant is attached to the nanoparticle, by reacting the nanoparticle with a metal alkoxide intermediate of the sequestrant having the general formula:



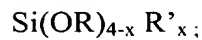
wherein M is silicon, titanium, aluminum, tin, or germanium;

x is an integer from 1 to 3;

5 R is an organic group; and

R' is an organic group containing an alpha amino carboxylate, a hydroxamate, or a catechol.

10 17. The composition of matter of claim 1 wherein said metal-ion sequestrant is attached to the nanoparticle by reacting the nanoparticle with a silicon alkoxide intermediate of the sequestrant having the general formula:



15 wherein x is an integer from 1 to 3;

R is an alkyl group; and

R' is an organic group containing an alpha amino carboxylate, a hydroxamate, or a catechol.

20 18. The composition of matter of claim 1 wherein said inorganic nanoparticles have a specific surface area of greater than 100 m<sup>2</sup>/g.

19. The composition of matter of claim 1 wherein said inorganic nanoparticles have a specific surface area of greater than 200 m<sup>2</sup>/g.

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20. The composition of matter of claim 1 wherein said inorganic nanoparticles have a specific surface area of greater than 300 m<sup>2</sup>/g.

30 21. The composition of matter of claim 9 wherein said inorganic nanoparticles have a specific surface area of greater than 300 m<sup>2</sup>/g.

22. The composition of matter of claim 1 wherein substantially all the metal-ion sequestrant is covalently bound to the nanoparticles.

23. The composition of matter of claim 1 wherein greater than  
5 95% by weight of the inorganic nanoparticles have a particle size of less than 200 nm.

24. The composition of matter of claim 1 wherein greater than  
95% by weight of the inorganic nanoparticles have a particle size of less than 50  
10 nm.

25. An article comprising a polymeric layer, said polymeric layer further comprising immobilized derivatized nanoparticles comprising inorganic nanoparticles having an attached metal-ion sequestrant, wherein said inorganic  
15 nanoparticles have an average particle size of less than 200 nm and the derivatized nanoparticles have a stability constant greater than  $10^{10}$  with iron (III).

26. The article of claim 25 wherein the polymeric layer is located on the surface(s) of the article.

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27. The article of claim 25 wherein the polymeric layer is permeable to liquid media.

28. The article of claim 25 wherein the polymeric layer is  
25 permeable to aqueous media.

29. The article of claim 28 wherein the polymeric layer has a water permeability of greater than  $1000 [(cm^3 cm)/(cm^2 sec/Pa)] \times 10^{13}$ .

30. The article of claim 28 wherein the polymeric layer has a water permeability of greater than  $5000 [(cm^3 cm)/(cm^2 sec/Pa)] \times 10^{13}$ .

31. The article of claim 25 wherein the polymeric layer comprises one or more of polyvinyl alcohol, cellophane, water-based polyurethanes, polyester, nylon, high nitrile resins, polyethylene-polyvinyl alcohol copolymer, polystyrene, ethyl cellulose, cellulose acetate, cellulose nitrate, aqueous latexes, polyacrylic acid, polystyrene sulfonate, polyamide, polymethacrylate, polyethylene terephthalate, polystyrene, polyethylene, polypropylene or polyacrylonitrile, or copolymers thereof.

32. The article of claim 25 further comprising a barrier layer; wherein the polymeric layer is between the surface of the article and the barrier layer and wherein the barrier layer does not contain the derivatized nanoparticles.

33. The article of claim 32 wherein the barrier layer is permeable to liquid media.

34. The article of claim 32 wherein the barrier layer is permeable to aqueous media.

35. The article of claim 34 wherein the barrier layer has a water permeability of greater than  $1000 [(cm^3 cm)/(cm^2 sec/Pa)] \times 10^{13}$ .

36. The article of claim 34 wherein the barrier layer has a water permeability of greater than  $5000 [(cm^3 cm)/(cm^2 sec/Pa)] \times 10^{13}$ .

37. The article of claim 32 wherein the barrier layer has a thickness in the range of 0.1 microns to 10 microns.

38. The article of claim 32 wherein the barrier layer comprises one or more of polyvinyl alcohol, cellophane, water-based polyurethanes, polyester, nylon, high nitrile resins, polyethylene-polyvinyl alcohol copolymer, polystyrene, ethyl cellulose, cellulose acetate, cellulose nitrate, aqueous latexes, polyacrylic acid, polystyrene sulfonate, polyamide, polymethacrylate, polyethylene

terephthalate, polystyrene, polyethylene, polypropylene or polyacrylonitrile, or copolymers thereof.

39. The article of claim 32 wherein the barrier layer prevents the  
5 diffusion or passage of micro-organisms.

40. The article of claim 32 wherein the barrier layer has a greater water permeability than the polymeric layer.

10 41. The article of claim 25 wherein said inorganic nanoparticles have an average particle size of less than 100 nm.

42. The article of claim 25 wherein said inorganic nanoparticles have an average particle size of less than 20 nm.

15 43. The article of claim 25 wherein said inorganic nanoparticles have a specific surface area of greater than 100 m<sup>2</sup>/g.

44. The article of claim 25 wherein said inorganic nanoparticles  
20 have a specific surface area of greater than 200 m<sup>2</sup>/g.

45. The article of claim 25 wherein said inorganic nanoparticles have a specific surface area of greater than 300 m<sup>2</sup>/g.

25 46. The article of claim 42 wherein said inorganic nanoparticles have a specific surface area of greater than 300 m<sup>2</sup>/g.

47. The article of claim 25 wherein greater than 95% by weight of the inorganic nanoparticles have a particle size of less than 200 nm.

30 48. The article of claim 25 wherein greater than 95% by weight of the inorganic nanoparticles have a particle size of less than 50 nm.